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**H04Q 7/04**

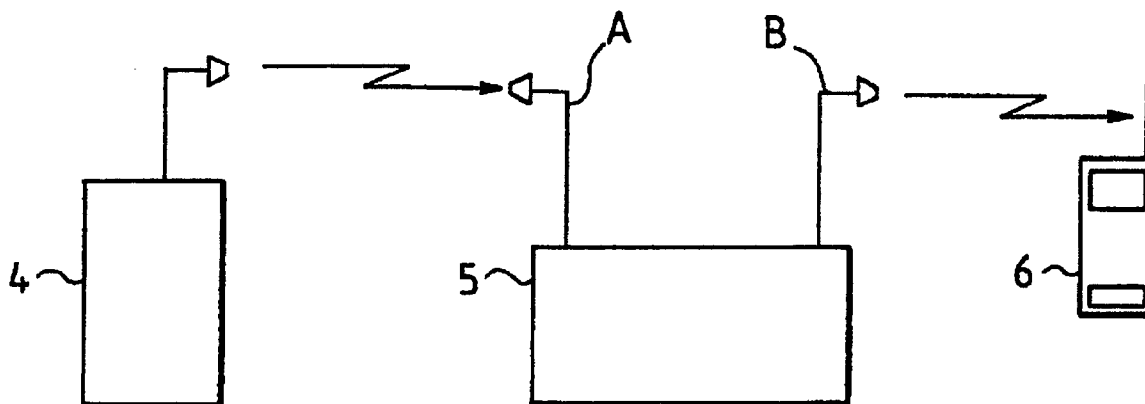
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**GB 2242337 A**      **GB 2237478 A**

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UK CL (Edition L ) **H4K**  
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(54) **A method of cellular radio communication and a cellular radio system for use in such method**

(57) In a method for improving radio coverage in a cellular radio system which comprises at least one base station 4 and a plurality of mobile stations 6 communicating with said base station 4, and at least one repeater station 5 for retransmitting messages received from the base station 4 to at least one mobile station 6, a first communication channel to a mobile station 6 is converted in the base station 4 into a second communication channel having a frequency offset from the first channel, in order to send a message to a repeater station 5 on the second channel. Correspondingly, in the repeater station 5, the message is received on the second channel, the second channel is converted back to the first channel, and finally, the message is transmitted to the mobile station 6 on the first channel.



**FIG. 2**

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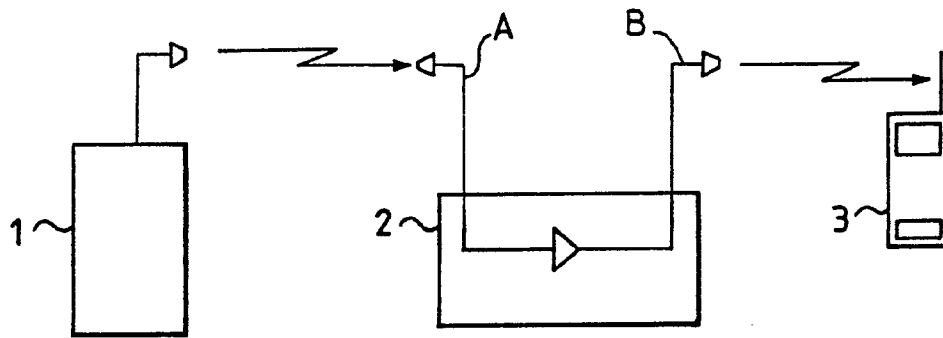


FIG. 1

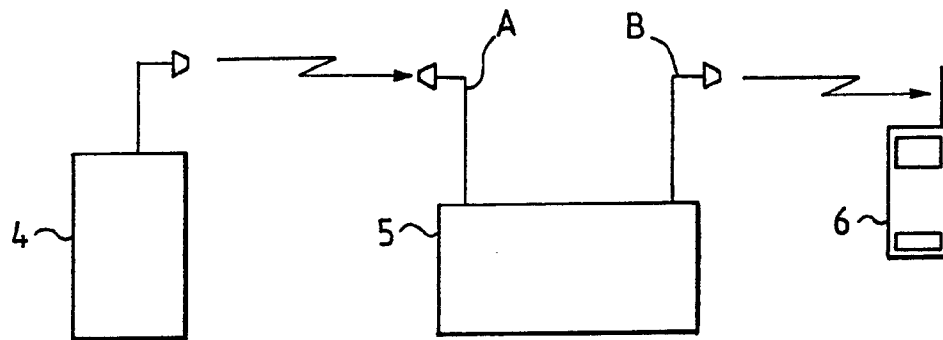


FIG. 2

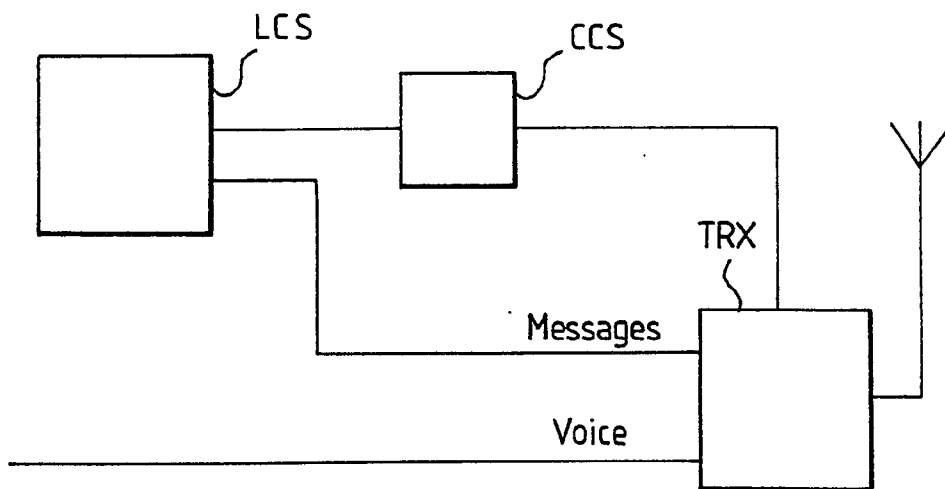


FIG. 3

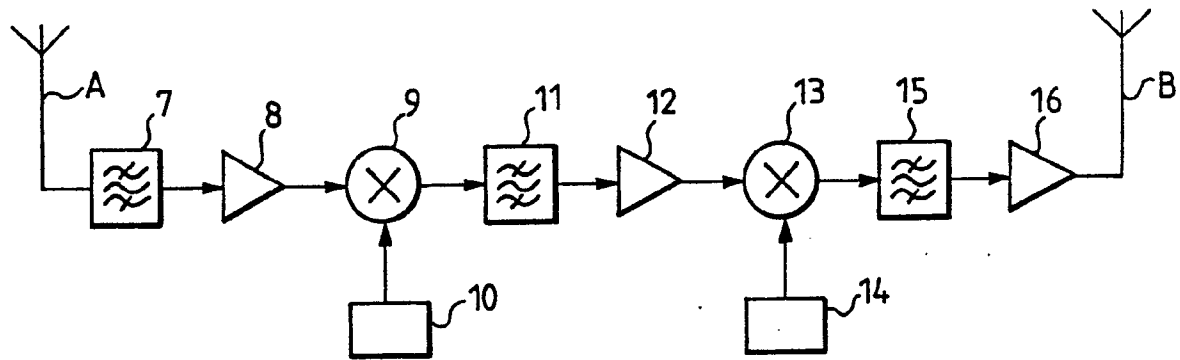


FIG. 4

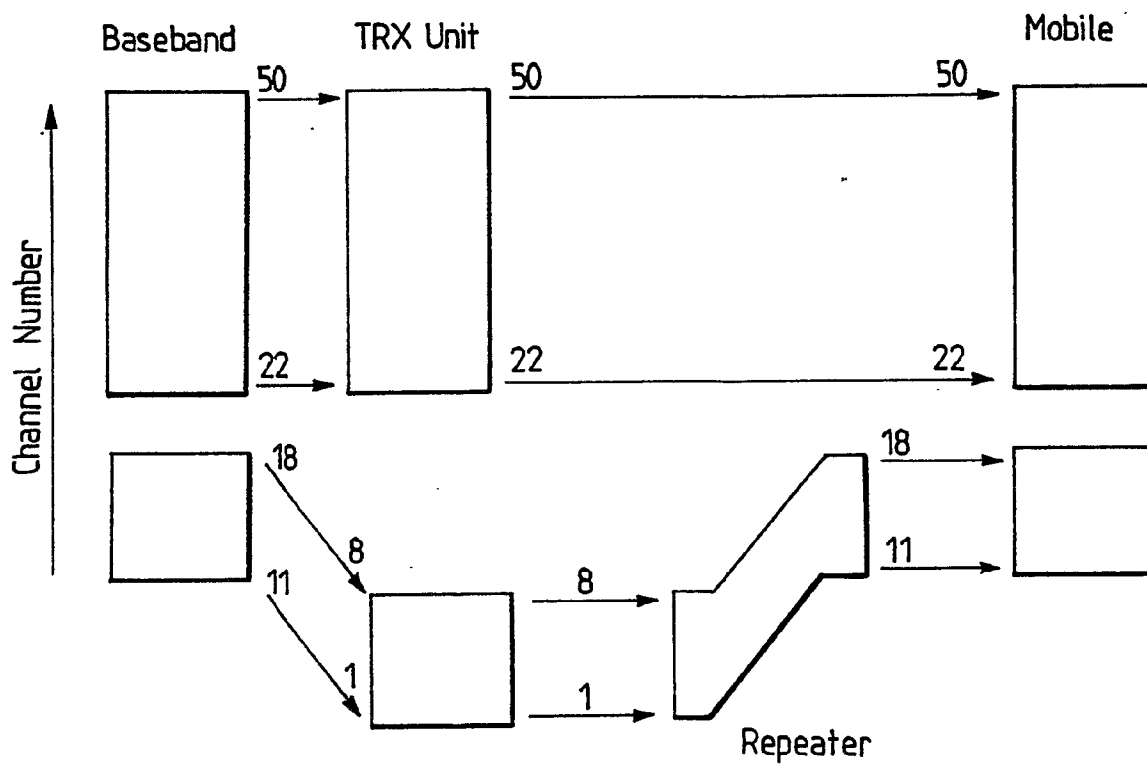


FIG. 5

A method of cellular radio communication and a cellular radio system for use in such a method.

5       The present invention relates to a method for improving radio coverage in a cellular radio system comprising at least one base station and a plurality of mobile stations communicating with said base station, and at least one repeater station retransmitting messages received from the base station to at least one mobile station.  
10       on.

      The invention also concerns a cellular radio system operating according to this method.

      Cellular radio systems rely on a network of radio base stations. The base stations communicate by means of  
15       radio signals with the mobile terminal, which may be a handportable radio telephone or may be a telephone in a car, or may be some other kind of equipment which is gaining access to the radio network. In principle, it should be possible for a subscriber to make or receive a call  
20       anywhere within the supposed region in which the network operator is offering service.

      In practice, there are always places where coverage is poor. For instance, indoor coverage is generally worse than outdoor and built-up areas tend to be worse than  
25       areas of open terrain. Usually, a network operator will compensate for this by installing more base stations in regions where the coverage is poor. However, there are new cellular radio systems under development which operate at a substantially higher radio frequency, which pose a  
30       greater problem in establishing good coverage. For instance, services based on the new DCS1800 standard will be operating in the region of 1800 MHz, double the frequency of existing cellular services. At these higher frequencies, the coverage area from a single base station is reduced by a factor of at least four. To achieve the same  
35

degree of coverage, the number of base stations must be greatly increased, which means that the infrastructure cost will also be greatly increased.

5 A possible alternative to installing more base stations is to install a mixture of base stations and radio repeaters. A radio repeater takes the radio signal from the base station, amplifies it, and re-transmits it to the mobile. It also receives signals from the mobile and re-transmits them to the base station. If a repeater is installed at some distance from the base station, it can improve local coverage in an area where coverage would otherwise be poor. Repeaters are commonly used in this matter for TV and other radio systems, and to some extent in cellular radio.

15 A major problem with repeaters in cellular radio, which is solved by this invention, is the need to maintain isolation between the receiving antenna and the transmitting antenna. As radio signals from the base station are received by the repeater by an antenna, the repeater then amplifies the signals, typically by 60dB. The amplified signals are re-transmitted by the repeater by another antenna to the mobile. If, through poor design or incorrect installation, signals from the second transmitting antenna are received by the first receiving antenna, it is possible that a feedback loop occurs, whereby the repeater re-amplifies the same signals until it becomes saturated. In such a condition the repeater will cease to function as a repeater and will merely transmit a maximum-power signal, causing interference to other network users.

25 This condition may be difficult to avoid, whilst still having sufficient amplification for the repeater to be effective. Normally, the two antennas of a repeater station will have to be physically well separated, perhaps with one antenna atop a tower, and the other at the bottom, the receiving antenna being highly directional in

favours of signals transmitted from the base station. The practical problem of installing antennas with perhaps 80 dB isolation between them makes the installation expensive. The physical separation requires towers, feed cables and so on, and then the radio frequency testing and commissioning must be conducted by highly skilled technicians.

The object of the present invention is to overcome the drawbacks and difficulties explained above. In order to achieve this object, the inventive method is characterized by the steps of

- converting in the base station a first communication channel to a mobile station into a second communication channel having a frequency offset from said first channel, in order to send a message to a repeater station on said second channel;

- receiving in the repeater station said message on said second channel;

- converting in said repeater said second channel back to said first channel; and

- transmitting said message to said mobile station on said first channel.

There are two essential components in the method according to the present invention. The first is that the repeater re-transmits on frequencies different from those it receives. The second is that the base station uses a different frequency from that which it commands the mobile to use. Consider first the repeater. The repeater receives signals on one or more carrier frequencies and re-transmits essentially similar signals on one or more different RF carrier frequencies. This eliminates the risk of the repeater suffering instability as a result of feedback from one antenna to the other. There is indeed some possibility of re-amplification of the signals transmitted by the repeater, but such re-transmission will now be on a differ-

ent frequency and can be arranged to lie outside the operational bandwidth of the equipment.

Now consider the base station and its communication with the mobile. Normally, a base station will transmit messages to the mobile, both during call set-up and while the call is in progress, which instruct the mobile to use a particular radio frequency. If a frequency-shifting repeater were used in conjunction with a conventional base station, then there would be a problem with base station to mobile communications via the repeater. The mobile would be instructed by the base station to use a particular radio frequency but when base station and mobile use that frequency, the repeater would introduce a frequency offset into the communication which would disrupt the link. So far as the mobile was concerned, the signals it was receiving would be on the wrong frequency. The present invention overcomes this problem by causing the base station to offset the frequency of its transmission by a certain amount, so that the repeater shifts the transmission back to a frequency which is consistent with the control signals that are being sent to the mobile.

The invention enables the use of repeaters with low installation cost, having eliminated the risk of feedback instability in the repeater. The antenna installation is much simpler, reducing the total infrastructure cost, whilst enabling a higher amplification to be used in the repeater. Despite the complication in the channel allocation at the base station end of the link, the changes are transparent to the mobile, so that no modification needs to be made to the mobile. Furthermore, it can be shown that in the preferred embodiment, it is possible to make the base station modifications without changes to the hardware or site visits. All radio links, whether direct or via the repeater, use the normal frequency bands and protocols so that the invention may be employed without

having additional frequency bands allocated for the network and without change to the regulatory certification of the equipment.

The characteristics of the preferred embodiments of the method and the cellular radio system according to the present invention are set forth in the attached claims.

The invention is hereinafter explained in detail by means of examples referring to the attached drawings, in which

figure 1 shows the general situation of downlink transmission via a repeater,

figure 2 shows the downlink transmission situation according to the present invention,

figure 3 shows a preferred embodiment of a base station according to the present invention,

figure 4 shows a preferred embodiment of a repeater according to the present invention,

figure 5 is a frequency allocation scheme for the network.

Considering now figure 1, the basic situation in a cellular network with repeater links is shown. Radio signals from the base station 1 are received by the repeater 2 by an antenna A. The repeater 2 amplifies the signals, typically by 60dB. The amplified signals are re-transmitted using the same frequency by the repeater with an antenna B to a mobile 3. This prior art system is afflicted with all the drawbacks and problems explained above.

The present invention is illustrated in Figure 2. The base station 4 instructs the mobile 6 to use Channel X. The base station 4 is, however, transmitting on Channel Y. The repeater 5, however, translates Channel Y into Channel X, whilst also amplifying it, and the mobile receives a signal which is on Channel X.

This method applies both to calling (signalling) channels, which, amongst other things, may instruct the mobile to use



a certain voice channel (i.e. channel X), and to the voice channel itself. On the other hand, without modifications in the mobiles it is not possible for a mobile to establish a call via the radio frequency that is intended for the base station to repeater part of the link. This implies that certain frequencies will have to be used for the base station to repeater link, and different frequencies for direct communication between the base station and the mobile (cf. fig. 5).

10       A preferred embodiment of the base station is illustrated in Figure 3, which shows the signal processing in the base station. Again, for clarity, only the downlink path is shown. The principle of operation is the same for the uplink path. Within the base station, an extra software module CCS is inserted into the channel selection control of the base station, between the Link Control Software LCS and the TRX unit, which is the sub-system which transmits and receives radio signals, converting between RF signals and baseband signals. The extra software module CCS is a Channel Conversion Software, and it translates the channel number that is requested by the link control software into a new channel number that is consistent with the operation of the repeater.

25       The TRX unit is primarily hardware and is responsible for putting voice and data information onto the air interface, and for receiving the air interface and extracting voice and data information. The LCS is primarily software and is responsible for control of the transmission links.

30       The software module CCS may be down-loaded into the equipment remotely and is simple to design because it may be an independent part of the link control software. Messages and voice traffic are carried out in the normal way through the TRX unit.

35       In figure 4, which shows the signal processing in

the repeater, the signals from the base station are received at antenna A. The signals are filtered and amplified in a filter 7 and an amplifier 8, respectively. The signal is then mixed by a mixer 9 using a local oscillator 10. This reduces the signal to a frequency of typically 150 MHz. A SAW (Surface Acoustic-Wave) filter 11 band-limits the signal, a second amplifier-12 amplifies it, whereafter it is up-converted in a second mixer 13 with a second local oscillator 14. Finally the signal is filtered with a filter 15 and put through a power amplifier 16 for transmission from antenna B. The SAW filter filters a fixed band, and by making the local oscillators 10 and 14 to have different frequencies, it is possible to shift the frequency of the in-band signals between reception at antenna A and transmission at antenna B. Preferably, the local oscillators 10 and 14 are both programmable, which enables the amount of frequency shift and the centre frequency of the re-transmitted band to be dynamically altered, according to the traffic load and other circumstances. The programming is preferably done by remote control, e.g. from a base station or a switching center of the cellular system.

Figure 5 shows a typical frequency allocation plan which might be used in connection with the present invention. The link control software of the base station allocates channels to links in the ranges 11 - 18 and 22 - 50. The Channel Conversion Software (see figure 3) translates the TRX frequency control programming so that channels 11 to 18 are converted to channels 1 to 8. Channels 22 to 50 are unaffected. The repeater converts channels 1 to 8 back to channels 11 to 18. Thus the base station may communicate with a mobile on any of channels 22 to 50 if the communication is direct, or on any of channels 11 to 18 if via a repeater. Channels 9, 10 and 19 to 21 are unused to avoid possible edge of band problems. Other frequency

plans are also possible to use, and if the band is split into three or more sections, the repeaters can be daisy-chained, whereby the frequency allocation plan is used to provide different channels for communication between each pair of repeater stations, e.g. in order to cover with one single base station a greater and/or a topographically very demanding area, than has been possible with prior art solutions.

In order to provide the maximum flexibility for the repeater as a product, and to enable a network to be re-configured during service, it is important for the repeater to be remotely configurable. Such dynamic control of the frequency offset and centre frequency is effected using an operations and maintenance interface, over a radio modem link.

It is clear for one skilled in the art that the various embodiments of the present invention are not restricted to the examples described above, but that they may vary within the scope of the attached claims.

## Claims

1. A method for improving radio coverage in a cellular radio system, comprising at least one base station and a plurality of mobile stations communicating with said base station, and at least one repeater station retransmitting messages received from the base station to at least one mobile station;

characterized by the steps of:

- 10       - converting in the base station a first communication channel to a mobile station into a second communication channel having a frequency offset from said first channel, in order to send a message to a repeater station on said second channel;
- 15       - receiving in the repeater station said message on said second channel;
- converting in said repeater said second channel back to said first channel; and
- transmitting said message from said repeater station to said mobile station on said first channel.

2. A method for improving radio coverage in a cellular radio system according to claim 1, characterized in that the base station simultaneously uses the first channel for direct communication with a mobile station and the second channel for communication with the same mobile station via said repeater station.

3. A method for improving radio coverage in a cellular radio system according to claim 1 or 2, characterized by that the repeater station is dynamically programmed to set the frequency offset and/or the centre frequency of the re-transmitted band.

4. A method for improving radio coverage in a cellular radio system according to any one of claims 1 to 3, characterized by using a frequency allocation plan in the base station for splitting up the frequency

band into sections in order to allocate channels between repeater stations and mobile stations

5 5. A method for improving radio coverage in a cellular radio system according to claim 4, characterized in that said frequency allocation plan is used to provide different channels for communication between each pair of repeater stations in a row of daisy-chained repeater stations.

10 6. A cellular radio system comprising:  
 - at least one base station set to communicate with a plurality of mobile stations; and  
 - at least one repeater station set to retransmit signals received from the base station to mobile stations;

15 characterized in that  
 - the base station includes means for converting a first communication channel to a mobile station into a second communication channel having a frequency offset from said first channel, in order to send a message to a repeater station on said second channel,  
 20 - the repeater station includes means for receiving said message on said second channel, means for converting said second channel back to said first channel, and means for transmitting said message to a mobile station on said first channel.

25 7. A cellular radio system according to claim 6, characterized in that the base station simultaneously uses the first channel for direct communication with a mobile station and the second channel for communication with the same mobile station via  
 30 a repeater station.

8. A cellular radio system according to claim 6 or 7, characterized in that the repeater station is programmable for a dynamic control of the frequency offset  
 35 and/or the centre frequency of the re-transmitted band.

9. A method for improving radio coverage in a cellular radio system substantially as hereinbefore described with reference to figs. 2 to 5 of the accompanying drawings.

10. A cellular radio system substantially as hereinbefore described with reference to figs. 2 to 5 of the accompanying drawings.

**Patents Act 1977**  
**Examiner's report to the Comptroller under**  
**Section 17 (The Search Report)**

-12-

Application number

GB 9223703.1

**Relevant Technical fields**

(i) UK Cl (Edition L ) H4K

(ii) Int Cl (Edition 5 ) H04Q

**Databases (see over)**

(i) UK Patent Office

(ii) ONLINE : WPI

Search Examiner

A L STRAYTON

Date of Search

29 JANUARY 1993

Documents considered relevant following a search in respect of claims ALL

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2242337 A - page 4 lines 7-9	1,6
X	GB 2237478 A - page 4 lines 13-23	1,6

Category	Identity of document and relevant passages - 13 -	Relevance to class(s)

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